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FSI Report No. 221

LARGE COMMUNICATIONS PLATFORMS
VERSUS
SMALLER SATELLITES
A Systems Comparison

First Monthly Progress Report

October 18, 1978

Prepared for

NASA Headquarters
Office of Communications Programs
Washington, D. C. 20546

NASA Contract No. NASW-3212

Prepared by

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FIRST MONTHLY PROGRESS REPORT

This is the first monthly progress report on the "Preparation of Systems Comparisons of Large Communications Platforms with Smaller Satellites". This study is being performed by Future Systems Incorporated (FSI) for NASA Headquarters under NASA Contract No. NASW-3212. In accordance with the contract requirements, the progress report includes a quantitative description of the overall progress, an indication of any current problems and a discussion of the work to be performed during the next monthly reporting period. In addition we have included draft elements of the final report as an Annex to this progress report.

1.0 Description of Progress

The effective date of the Contract is September 15, 1978 and the final report is to be delivered by January 31, 1979. Monthly progress reports are due by mid month for October, November and December. During the first study month, work proceeded in accordance with the schedule submitted in the FSI Technical Proposal dated May 3, 1978, and the work accomplished falls in three subtasks:

Collection of Applicable Information
Preparation of an Outline for the Final Report
Preparation of Traffic Models
Synthesis of Platform Communications Systems

1.1 Collection of Applicable Information

During the past year, considerable attention has been focused upon the question of large capacity communications satellites, possibly combined with other non-communications payloads on multi-function platforms. Work in this area was done by NASA Headquarters and NASA Centers, as well as by the industry. In order to make the present FSI study as realistic as possible, we have established

contact with key individuals at various interested organizations and have surveyed their views and collected available information on the subject of large communications platforms. In addition to NASA Headquarters we have visited the following NASA Centers:

Center	Key Contact
George C. Marshall Space Flight Center	Mr. William T. Carey, Jr.
NASA Goddard Space Flight Center	Dr. John H. McElroy
NASA Lewis Research Center	Mr. Joseph N. Sivo

Marshall Space Flight Center has issued study contracts concerning large platforms to Aerospace Corporation and to COMSAT Laboratories. These studies involve the design of antennas, switches, transponders and other spacecraft aspects. FSI has held discussions with representatives of both organizations.

In addition, it is important to consider the views of communications carriers who may become users of the large communications platforms. FSI has visited Western Union and INTELSAT for initial discussions of this subject.

Technical articles and other documents that are relevant to this study have been collected and are listed in the reference section of the Annex to this progress report.

1.2 Preparation of an Outline for the Final Report

A tentative outline for the final report has been prepared and is reflected in the Table of Contents of the Annex section. The final report will be issued in two volumes: Volume I will consist of a comprehensive summary of all work and conclusions, and Volume II will contain detailed back-up data and calculations.

1.3 Preparation of Traffic Models

FSI will analyze two separate systems. One system will provide service for U. S. domestic requirements and the other system will be designed to satisfy Atlantic INTELSAT requirements. The two systems will be interconnected by intersatellite links in order to avoid the need for terrestrial extensions or multi-hop operation. Work on the traffic models is in progress.

1.4 Synthesis of Platform Communications Systems

Initial work was done on the synthesis of communications systems using large platforms. The basic approach used in the study is described in the Annex section.

2.0 Indication of Problems

All work has progressed on schedule and no problems have developed which would impede contractor performance.

3.0 Work to be Performed During the Next Reporting Period

The second monthly progress report is due by mid November 1978. It will cover work to be performed during the second study month, as follows:

Additional discussions with NASA Centers, Communications Carriers and Industry

Up-dating of Traffic Models

Synthesis of Communications Systems Using Large Platforms

Synthesis of Communications Systems Using Conventional Satellites

ANNEX
DRAFT ELEMENTS OF FINAL REPORT

This Annex contains the tentative Table of Contents for the Final Report, as well as draft elements for the Final Report.

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Volume I - Summary and Conclusions

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ACKNOWLEDGEMENTS

This study was performed with direction from Mr. Samuel W. Fordyce, NASA Technical Contract Monitor. In addition to the valuable guidance received from him, FSI had the opportunity of discussing the study and the systems concepts described in the report with individuals from the organizations listed below. Suggestions and recommendations received from these individuals have contributed substantially to this report and these contributions are greatfully acknowledged. FSI alone, however, accepts full responsibility for all contents of the report. Only one single individual is listed for each organization, although in many cases more than one individual participated in the discussions.

ORGANIZATION	MAIN CONTACT
George C. Marshall Space Flight Center	Mr. William T. Carey, Jr.
NASA Goddard Space Flight Center	Dr. John H. McElroy
NASA Lewis Research Center	Mr. Joseph N. Sivo
Aerospace Corporation	Mr. Ivan Beckey
COMSAT Laboratories	Dr. Burton I. Edelson
INTELSAT	Dr. NandKishore Chitre
Western Union Telegraph Company	Mr. Thomas Gabriszeski

VOLUME I

SUMMARY AND CONCLUSIONS

TABLE OF CONTENTS

SECTION 2
INTRODUCTION

This report has been prepared by Future Systems Incorporated (FSI) for NASA Headquarters under Contract No. NASW-3212. The report describes a study which compares communications systems using large communications platforms with systems using conventional satellites. The context of this study within NASA's overall communications program is described below.

NASA has developed a 5-year plan for its communications program (Reference 1). This plan is designed to enable growth in the capacity and utilization of the radio frequency spectrum, to develop technology which will lead to a reduction in communications service costs and to serve as a catalyst in the creation of new services in the public interest. NASA programs consist of three phases: pre-project studies, technology verification and technology applications.

Pre-project studies consist of system assessment studies and of advanced system definition studies. The objectives for the pre-project studies are to:

1) Provide an assessment of requirements for systems capabilities
2) Provide the technical, programmatic and institutional analysis for value assessment of potential operational communications satellite systems
3) Provide a focus for a communications technology program

In the area of Advanced System Definition Studies, NASA's current effort is concentrated upon wideband systems, narrowband systems and large capacity aggregate systems (platforms). The objectives of these studies are as follows:

Wideband System

Define an economical 18/30 GHz communications satellite system to provide high capacity direct to the user and trunking services in a spectrum conservative fashion

Narrowband System

Define an economically viable and institutionally acceptable satellite system for thin-route fixed and land mobile services below 3 GHz in a spectrum conservative fashion

Large Capacity Aggregate Systems

Assess the overall utility of using large geostationary platforms as a means of accommodating future missions and payloads in lieu of individual, smaller satellites

It is clear that large capacity aggregate systems may well include wideband and narrowband system payloads, along with a variety of other payloads. Thus, the three systems that are being studied are not competitive alternatives but are complimentary to each other, although it may be necessary to establish priorities for technology development and implementation of these systems.

The large capacity systems platforms study considers platforms with multi-discipline payloads. Depending on the size of the platform, multi-Shuttle launch may be required with consequent in-space assembly. At certain levels of complexity, periodic space maintenance will become important.

To many experts it has been intuitively obvious that large aggregate platforms will have an overall cost advantage relative to systems with small separate satellites (Reference 2). In addition, Marshall Space Flight Center has conducted a cost benefit analysis for the space segment only of large communications platforms relative to smaller separate satellites (Reference 3). This analysis

showed that for the specific set of assumptions made, the large platform concept offers significant advantages over smaller separate satellites. However, prior to the present FSI study there has been no systematic analysis of overall cost benefits of large platform systems relative to systems with smaller separate satellites including space segment as well as ground segment.

The purpose of the present FSI study has thus been the cost comparison of large capacity communications platforms with separate smaller satellites on a systems basis, considering total costs to the end user. The cost comparison has been performed for two specific systems: a system to provide communications for U. S. domestic applications and a system to serve the Atlantic INTELSAT requirements. These simple platform applications have been selected because they minimize associated institutional problems. Of course they do not exploit the full advantages that can ultimately be obtained from large platforms with multi-discipline missions. However, to the extent that these simple platforms demonstrate cost benefits, such benefits can be further enhanced by the addition of other payloads to the platforms.

SECTION 3
SYSTEMS CONSIDERATIONS

3.1 Geostationary Platform Mission Capabilities

According to Reference 4, geostationary platforms may provide the following mission capabilities:

Fixed Communications Satellite Service (Point-to-Point)

C-band as provided by Comstar, Satcom, Westar and Anik

11/14 GHz as planned by Advanced Westar and SBS

18/30 GHz as in the wideband system studied by NASA Lewis Research Center

S-band thin route communications, as in the system studied by NASA Goddard Space Flight Center

Mobile Satellite Communications Service

L-band for communications with ships as in Marisat and as planned for Marots and Inmarsat

VHF and L-band communications with aricraft as was planned for Aerosat

L-band for land mobile services

Broadcasting Satellite Services

S-band TV broadcasting, as conducted on ATS-6 and as planned for Insat

11/14 GHz broadcasting as conducted on CTS and on Japan's BS Program

Space Research, Meteorology and Earth Observation

Space-to-space communications experiments, for example, at 60 GHz

Follow-on program to provide the TDRSS function

Meteorology as in the SMS and GOES programs

Earth observation from geostationary orbit

Reference 5 lists a similar set of services, as repeated below:

Intercontinental Trunking
Regional and Domestic Trunking
Regional and Domestic Networks
Business Networks
Maritime Services
Aeronautical Services
TV Distribution
TV Broadcast
Educational TV
Bush Voice
CB/Amateur
Intersatellite
Standard Time/Frequency
Disaster Communications
Navigation
Meteorology Earth Exploration

In addition to providing a large variety of service types, as identified in the above-mentioned references, platforms can provide the same type of service for diverse geographical locations. As identified in Reference 5, a platform for the Americas can provide domestic communications services for the USA, Canada and for all Latin American countries. The same is true for other services such as meteorology and earth observation. Thus a single platform can provide about fifteen different services and many of them to perhaps ten different countries as well as international and regional services. A total of over 100 different missions is well possible on a major platform system. However, it is not likely that a first generation platform system will contain that many missions, primarily for institutional reasons.

3.2 Platform Missions Considered in this Study

In order to improve the probability of an institutional solution to the platform problem, we have included only a small subset of the possible platform missions in this first analysis. Two platform categories configured for the missions are identified below:

Platform Type A: U.S. Domestic Communications Services

This platform provides the following service categories:

Trunk service at C-band
Trunk service at Ku-band
Trunk service at 18/30 GHz

Direct-to-the-user service at C-band
Direct-to-the-user service at Ku-band
Direct-to-the-user service at 18/30 GHz

Intersatellite links to other platforms

Geographical coverage is provided for CONUS, Puerto Rico, Hawaii and most of Alaska. Trunk and direct-to-the-user services are interconnected and all frequency bands are interconnected. Intersatellite links permit the interconnection of any earth station with other platforms for domestic and international services. Since the future location of trunking and direct-to-the-user earth stations cannot be determined at this time, continuous coverage of all land areas is provided at all frequency bands. Thin route fixed services are provided with low cost C-band earth stations.

Specifically excluded from this model are international and regional services, foreign domestic services, broadcasting services, land mobile services, space research, meteorology and earth observation. This exclusion does not imply any judgement concerning the desirability of including such services in an operational system. Also excluded are TV distribution services based on reasons described in Section 3.3.

Platform Type B: INTELSAT Atlantic Services

This platform provides the following service categories:

- INTELSAT's international services based on an extension of its present traffic data base
- New international services made practical by the high capacity platform (e.g., video conferencing)
- Domestic and regional services for African and Latin American countries

Geographical coverage is provided to all land masses visible from a geostationary position over the mid Atlantic. International, regional and domestic services are fully integrated to provide full systems connectivity from any earth station in the network. Intersatellite links provide connectivity to other platforms of the INTELSAT System and of domestic systems in order to avoid the double-hop problem without the use of terrestrial extensions. Thin route services are possible with low cost C-band earth stations. A capability at Ku-band and at 18/30 GHz is also provided.

Excluded from this model are maritime and aeronautical communications services, broadcast services, TV distribution services, land mobile services, space research, meteorological and earth observation services. As for Platform Type A, this choice does not imply any judgement concerning the desirability of providing such services except for TV distribution.

3.3 Exclusion of TV Distribution Services

During the past 2 years, and especially during the past 6 months, there has been a very rapid increase in TV distribution services in the U.S. domestic satellite communications systems of RCA American Communications and Western Union Telegraph Company. The RCA System alone uses almost a full RCA Satcom satellite with 24 transponders for full time TV distribution. This rapid increase has exceeded most earlier forecasts for the carriers and by others. The costs of TV receive-only earth stations have dropped to the range of $20 to $30 k installed, and by 1979 it is expected that over 1,000 such stations will be in operation in the USA.

High capacity platforms achieve their capacity primarily through frequency re-use by means of multiple beams. This capacity multiplication works only for the case of point-to-point service. Multiple beams do not provide the same advantage when wide area distribution of a signal is required, as in the case of TV distribution. For this reason we expect that TV distribution will be provided by separate, small satellites even after large communications platforms have become operational. Satellites of the Satcom type with 24 transponders may be close to ideal for this purpose. Future satellites for TV distribution will probably be modified for smaller transponder bandwidth, since 36 MHz is more bandwidth than is needed for TV transmission. In addition it is possible that the antenna coverage will be adjusted to conform to the time zones so as to provide more flexibility in program distribution. The resulting satellites will have 36 to 48 TV transponders and will have a mass of about 700 kg beginning of life (BOL) in synchronous orbit.

It would be wasteful to use a large communications platform for TV distribution at a frequency band that is also used for point-to-point communications. For this reason we have excluded TV distribution from the platform missions, both for U.S. domestic and for INTELSAT services.

3.4 Complexity Inversion

A study performed by McDonnell Douglas for NASA Langley Research Center (Reference 6) identified the gradual complexity inversion in satellite communications. Initial commercial communications satellites had an extremely simple payload, leading to large and very expensive earth stations. As space technology progressed it became economical to increase spacecraft complexity and reduce earth station costs. This trend will be accelerated with the introduction of space platforms. Lower earth station costs will lead to a proliferation of earth stations, which means that more earth stations will be located closer to the end user. The result is a reduction in requirements for terrestrial extensions and interconnect facilities. This is especially important in cases where suitable terrestrial facilities do not exist and are difficult to implement, as is the case in developing countries for all communications services and in the USA for high speed data and video conferencing applications.

3.5 Modulation/Access Techniques

To date very little work has been done on the optimization of modulation/access techniques for large communications platforms. Since FSI has performed many trade-off studies for different modulation/access techniques, we have a good background in this area. However, a detailed trade-off could not be performed within the scope of the present study. Instead we have selected a modulation/access system which, based on our general background, we consider promising for the platform application.

Satellites which operate with a single transmit and receive antenna beam can be designed to operate with a wide range of modulation/access techniques. However, satellites with several or with many different antenna beams require provision for beam interconnection, and the method of beam interconnection may limit the choice of modulation/access technique. For example, INTELSAT V uses filter matrices to interconnect transmit and receive antenna beams. This limits the flexibility of traffic redistribution with changing demand and makes the system less suitable for TDMA transmission. On the other hand, Advanced Westar employs satellite-switched TDMA as modulation/access technique, and beam interconnection is accomplished by means of time division switching of a filter matrix. This system provides excellent flexibility since the switch timing can be ground programed, but the transmission system must rely exclusively upon satellite-switched TDMA transmission. It cannot use the single channel per carrier technique (SCPC) which is cheaper than the TDMA technique for low transmission volume per earth station.

For the communications platforms in this study, the number of antenna beams is much larger than for INTELSAT V and for Advanced Westar. For example, a total of 39 beams is employed for CONUS coverage alone, with additional requirements for Alaska, Puerto Rico, Hawaii and for interconnection of the different frequency bands within individual beams. On a satellite with 50 beams the required number of beam interconnect links is 1,275. With 100 beams a total of 5,050 interconnect links is required. The general expression is given as follows:

$$l = b(1 + \frac{b-1}{2})$$

where

l	=	Number of interconnect links
b	=	Number of antenna beams to be interconnected

This equation assumes that each beam must be connected to itself and to each other beam on the platform.

With a requirement of over 1,000 interconnect links the INTELSAT V technique which uses interconnection by means of filters is not practical. Likewise, the Advanced Westar technique of satellite-switched TDMA is undesirable for two reasons:

1) Because of the large number of switch modes required, the number of synchronization and overhead bits is very large. Thus, the frame efficiency would be low even with very long frame times, which require additional storage capability.

2) Earth stations have to transmit at a high bit rate and have to handle receive data which is of no interest. This increases earth station costs.

For these and other reasons we have selected a modified SCPC system as the access technique. A hierarchy of carrier sizes will be used, such as 64 kBps, 1.544 MBps, 6.3 MBps, etc. Each earth station transmits one carrier for each link on a pre-assigned or demand-assigned basis as required. The communications platform provides a switching capability to interconnect the various carriers to the respective beams at an IF frequency. This results in a very substantial platform requirement for frequency translation and IF switching equipment. However, the need for demodulation and remodulation of signals has been avoided, which would have been a further increase in complexity.

Although this system will work with FM carriers, we have selected PSK as the modulation technique, and we expect that forward error control coding will be used to permit operation in the interference environment that results from a large number of sidelobes in a multi-beam system.

3.6 Demand Assignment Versus Pre-Assignment

Figure 3-1 shows the Erlang load versus number of channels on a link. The ratio of number of pre-assigned channels to Erlangs is the concentration ratio that is achievable in a large demand assignment pool.

The Figure shows that very large concentration ratios are possible with small numbers of channels per link, but little concentration is available with large numbers of channels per link. For this reason traffic on large links, like between the New York - Los Angeles trunking stations, will be pre-assigned, but traffic on low capacity links will have to be demand assigned. This requires demand assignment control of the satellite frequency converter/switch assemblies which will be accomplished via a signaling channel system.

3.7 Earth Station Concept

With the selected system, earth stations become very simple. Each earth station transmits and receives a given number of digital carriers depending on its traffic requirements. Some larger carriers are pre-assigned, but most links will be demand assigned. Antenna diameters can be small because the satellites have narrow-beam, high-gain transmit and receive antennas. At C-band an antenna diameter of about 4 meters is adequate to permit continued operation of satellites with a spacing of 4 degrees. At higher frequencies it will be possible to employ smaller diameter antennas inversely proportional to the frequency and still maintain a 4-degree satellite spacing. Earth station HPA's will be replaced by low level amplifiers, generally below 1 watt RF power.

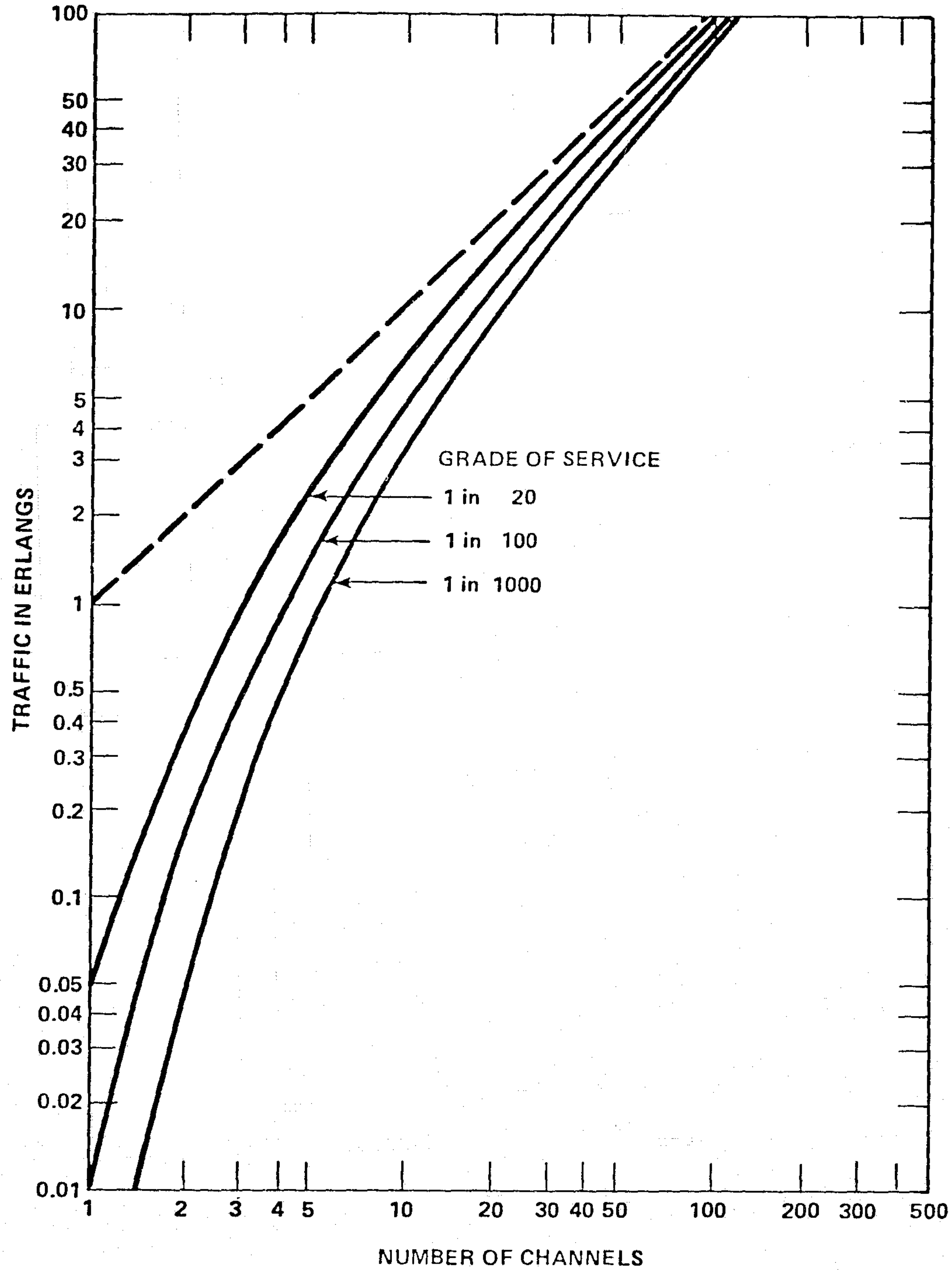

Figure 3-1

ERLANG LOAD VERSUS NUMBER OF CHANNELS

Since the satellite performs a substantial portion of the switching requirement, earth station baseband equipment is greatly simplified. Lower earth station costs will induce a proliferation of earth stations, and the larger production volumes will lead to further cost reductions. Typical earth station costs will range from $20 k to $100 k installed.

3.8 Platform Concept

One basic requirement for the platform antenna design is to provide continuous coverage of all land masses as compared to coverage of specific cities. This requirement follows from the inability of the carriers to predict where earth station locations will be selected in the future. The generation of the required beam patterns at six frequency bands will be a difficult task and may well lead to an implementation with several separate antennas, as has already been envisaged in the various artist's concepts that were presented in the literature (References 2, 5 and 7). If the platform is not sufficiently rigid, finepointing of individual antennas or feedclusters may be required.

In our baseline model we have assumed antenna beams with a 3 dB width of 0.75 degrees. Beam pointing stability should be better preferably by one order of magnitude. It was assumed that beams of this width represented an adequate challenge to antenna and spacecraft designers, and narrower beams than 0.75 degrees are left for later platform generations. Even with our assumptions the antenna design will be one of the difficult technology developments.

As described in Section 3.5, interconnection of the large number of beams is another technology development problem, probably more difficult than the antenna design, taking into account the requirement for high reliability and continuity of service.

With a large communications platform it is probable that the component count increases much more rapidly than the component reliability can be improved. This would lead to a reduction of platform lifetime unless in-orbit maintenance is introduced. Short lifetimes of expensive platforms will not be desirable and

therefore the platform concept includes in-orbit maintenance. This represents the third technology development problem, perhaps even more severe than the antenna and the switch.

For later generations of platforms it is possible that a permanently manned geostationary maintenance center is used to service several or perhaps all platforms in orbit. The maintenance center could be made to drift at a rate of 2 to 3 degrees per day, thus permitting visits to all space stations in 6- or 4-month intervals. A small manned mobile unit would detach from the maintenance center (whose drift rate is not changed) and would dock with the communications platform to perform the required maintenance which had been planned based on telemetry information. Maintenance center crew changes would be combined with scheduled restocking of maintenance modules. Failed and obsolete equipment would be removed from synchronous oribt. The maintenance center could be operated by an international venture.

For the first platform generation, however, manned maintenance has been judged to be too expensive, and NASA is proceeding with plans for an unmanned teleoperator. This device is being designed for initial application in low earth orbit but could later be adapted for operation in geostationary orbit. It would dock with the platform and replace modules as required. The platform and payloads would have to be designed specifically to permit teleoperator maintenance. Docking and maintenance maneuvers should not disrupt communications. Special attention will have to be given to the reliability of those platform and payload elements which are not subject to teleoperator maintenance. This applies, for example, to connectors, interconnect cabling and antenna feeds.

3.9 Diversity Operation

3.9.1 Satellite Diversity

Communications systems operators have traditionally sought to design their systems so as to provide path diversity. The objective is to minimize disruptions of the communications network in case of transmission link or switching

node failure. From this point of view, the concentration of all traffic of a given entity on a single platform will be an undesirable if not unacceptable feature, regardless of cost savings.

In order to maintain diversity, we expect that space and terrestrial transmissions will continue to be developed in a balanced fashion. This applies to international as well as to domestic telecommunications. In addition, we expect that there will continue to be a requirement to split traffic on high density routes among two or more satellite paths, as is now the case in the INTELSAT System where Primary and Major Path satellites are used in this fashion. It is especially important to avoid major losses of communications capacity in an automatic system, since the attempt to redial by a large number of users who experienced a busy signal could lead to a temporary breakdown of the complete system. For this reason, in assigning traffic to platforms, a minimum of two platforms will have to be used, or one platform augmented by smaller satellites.

3.9.2 Ground Diversity

In the past, ground diversity has also been used as a protection against earth station failure. For example, the satellite traffic between the USA and major European countries has been split between the Primary and the Major Path satellites, which are accessed by separate earth stations. This concept will remain in use for high traffic links; however, due to lower earth station costs a larger number of low capacity links will be established for which dual satellite and earth station operation will not be required. Some terrestrial facilities will, however, be desirable.

Diversity has also been considered as a means of avoiding propagation outages with transmission at higher frequencies. Such diversity operation is undesirable for low capacity applications because of the expense of the two earth stations separated by about 10 km and the associated interconnect link. A more desirable form of diversity is frequency diversity, whereby normal transmission is accomplished at the higher frequencies and where the lower frequencies are used only temporarily at earth stations while they experience heavy rain. This is

feasible only in systems in which the platforms provide on-board switching on a demand-assigned basis. It increases the earth station costs but it avoids the need for a second physical location and for the interconnect link. With this system a communications user will have the option of accepting the link availability that results from a single station operating at 18/30 GHz, or to pay the increased earth station cost for dual frequency operation with the resulting higher availability.

3.10 Platform Implementation Schedule

Based on discussions with various experts, initial commercial operation of large communications platforms would take place between 1987 and 1995. To the extent that large platforms lead to cost and other systems benefits, the cumulative advantages are greater if systems operation starts earlier. For this reason we have based our study on the earlier implementation date of 1987. This implementation time of 9 years is certainly adequate from a technology development and industry capability point of view, although it may require the resolution of some institutional questions.

Before discussing the schedule question in more detail, we would like to point out that much of the advantage of technology development would be lost if a long, drawn out implementation schedule is pursued. In the 1960's and early 1970's the European aerospace industry was in this situation. Largely because of institutional arrangements, the construction of the Symphonie satellites extended over a time span during which several generations of INTELSAT satellites were brought into service. Lately, however, the program cycle of the European space program has been shortened. For example, the ECS satellites follow OTS with very little delay, and a French domestic satellite system will probably be announced within the next few months.

A 1987 operational schedule will require that the first NASA platform becomes the pilot operational system for one of the applications. This may be contrary to normal NASA practices, where NASA flies experiments and the carriers fly operational systems. In the case of the platform, the expense is such that a different approach is desirable from a cost benefit point of view. A compression of

the schedule for start of commercial operation is also desirable from a public interest point of view, so that the platform's advantages are available to the public at an earlier date. Therefore, for the purpose of this study the following implementation scenario has been selected:

Program Element	Completion Date
Systems/Market Studies	September 1979
Concept Definition	December 1979
Design Program Definition	December 1981
Congressional Approval	March 1982
Design, Development and Construction	March 1986
Launch	June 1986
Pre-operational Tests	December 1986
Start of Commercial Operation	January 1987

SECTION 5
TRAFFIC MODELS

5.1 General Considerations

For the purpose of platform systems design, the following aspects of traffic models must be considered:

Total traffic
Geographical distribution of traffic
Number of links, channels per link
Pre-assigned and demand-assigned traffic

The total traffic defines the capacity requirement for the communications platform. The geographical distribution of traffic is important since it determines which satellite antenna beams will saturate first. The number of links and the number of channels per link provide an important input to the selection of a modulation/access technique for the system. The breakdown of pre-assigned versus demand-assigned traffic is required for the on-board switch design. Total traffic information is required as a function of time for calculation of systems economics and for determination of the saturation date.

In designing the system, actual traffic carried must be determined by iteration. This is due to the fact that the availability of new facilities will stimulate service demand and lower satellite transmission costs will change the balance of terrestrial versus satellite traffic. In this section, we have therefore presented our initial estimates for traffic. They will be modified in the course of the platform systems design.

5.2 U. S. Domestic Traffic

Our traffic forecast for U. S. domestic traffic includes the following types of services:

Telephony Traffic
Data Traffic
TV Distribution
Video Conferencing Traffic

The assumptions used in developing this scenario are listed below:

Large earth station networks
Planning towards large platforms
Rapid growth of video conferencing and electronic mail
Satellite systems grow faster than terrestrial systems
Satellites carry extensive MTS traffic

The forecast of conventional telephony traffic requirements is based on correlation factors which have been derived from historical data and are applied to forecasts of future population and GNP numbers. One very useful correlation factor was found to be the measure of GNP per telephone. It was found that this factor generally converges to similar numbers as each country progresses in its economic and technological development. Another important factor is the ratio of long distance telephone calls per telephone. Finally, we used the ratio of long distance calls per unit GNP as another correlation factor.

Extrapolation of historical data leads only to traffic estimates for the types of services which have been carried in the past. New technology and other changing conditions will lead to the introduction of new services for which traffic estimates must be based on market forecasts and on other considerations. One major category of new services is the type of data communications traffic which is the target of Satellite Business Systems (SBS). Our forecast for this type of service is based on the SBS market survey which was described in a 1976 filing. Included in our data forecast is demand for electronic mail service.

The traffic forecasts for voice, data and TV distribution resulting from these models are shown in Figure 5-1 and Table 5-1.

The demand for electronic mail was derived by considering GNP and first class mail per capita. A forecast was made for the growth of population GNP and mail per capita. By doing this forecast we were able to predict total first class mail volumes over the study period. An assessment was made of the percentage of first class mail suitable to electronic mail service, and this volume was converted into a transponder requirement assuming a transmission rate of 64 Mbps and a busy hour requirement of 1.5 times the average number of transponders required if the service was equally in demand 24 hours per day, 365 days per year. In addition, we have shown a range of demand as shown in Table 5-2 and Figure 5-2. The low traffic demand represents electronic mail being used for 10 percent of first class mail in the year 2003 and the high traffic demand represents 30 percent of first class mail in the year 2003.

The demand for video conferencing requirements shown in Table 5-3 and Figure 5-3 in thousands of circuits was derived by estimating the number of business trips which might be eliminated if video conferencing facilities were available.

As in our forecast of electronic mail requirements, we have produced demands for a range of traffic designated as low, medium and high. If the demand shown in Table 5-3 were to be translated in equivalent transmission capacity in transponders, it becomes apparent that special purpose satellites in conjunction with demand assignment will be required, since even in the low traffic model the equivalent numbers of C-band transponders in the year 2003 is on the order of 2,500.

5.3 INTELSAT Traffic

Figure 5-4 shows actual INTELSAT traffic from June 1969 to October 1977 as well as the INTELSAT traffic forecast and the FSI traffic forecast. Table 5-4 contains the INTELSAT information, and Table 5-5 shows the FSI forecast for INTELSAT traffic.

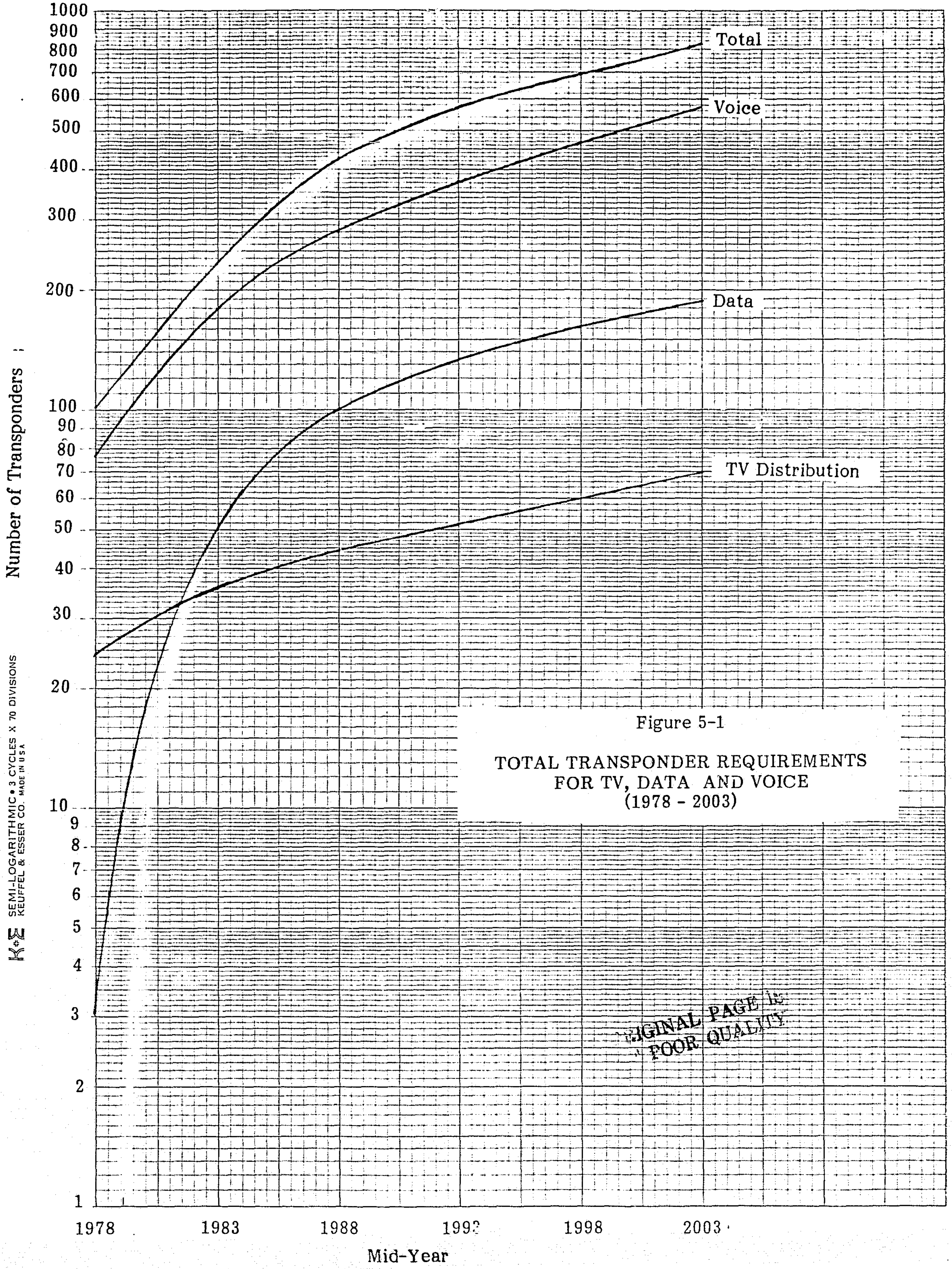

Figure 5-1

TOTAL TRANSPONDER REQUIREMENTS
FOR TV, DATA AND VOICE
(1978 - 2003)

Table 5-1
1978-2003 Traffic Demand for
TV, Data and Voice
(Transponders)

	1978	1983	1988	1993	1998	2003
Voice	77	180	279	373	465	565
Data	3	50.1	101.1	133.9	161.1	188.6
TV Distribution	24.6	35.9	44.2	51.8	59.9	69.2
Total	104.6	226.0	424.3	558.7	685.0	822.8

Table 5-2

1978-2003 Satellite Transponder Requirements

For Electronic Mail

Traffic Scenario	1978	1983	1988	1993	1998	2003
Low	0	.75	2.4	4.5	8.1	11.3
Medium	0	.75	4.1	10.8	20.1	28.1
High	0	1.5	5.7	12.6	25.2	33.6

Figure 5-2

SATELLITE TRANSPONDER REQUIREMENTS FOR ELECTRONIC MAIL (1978 - 2003)

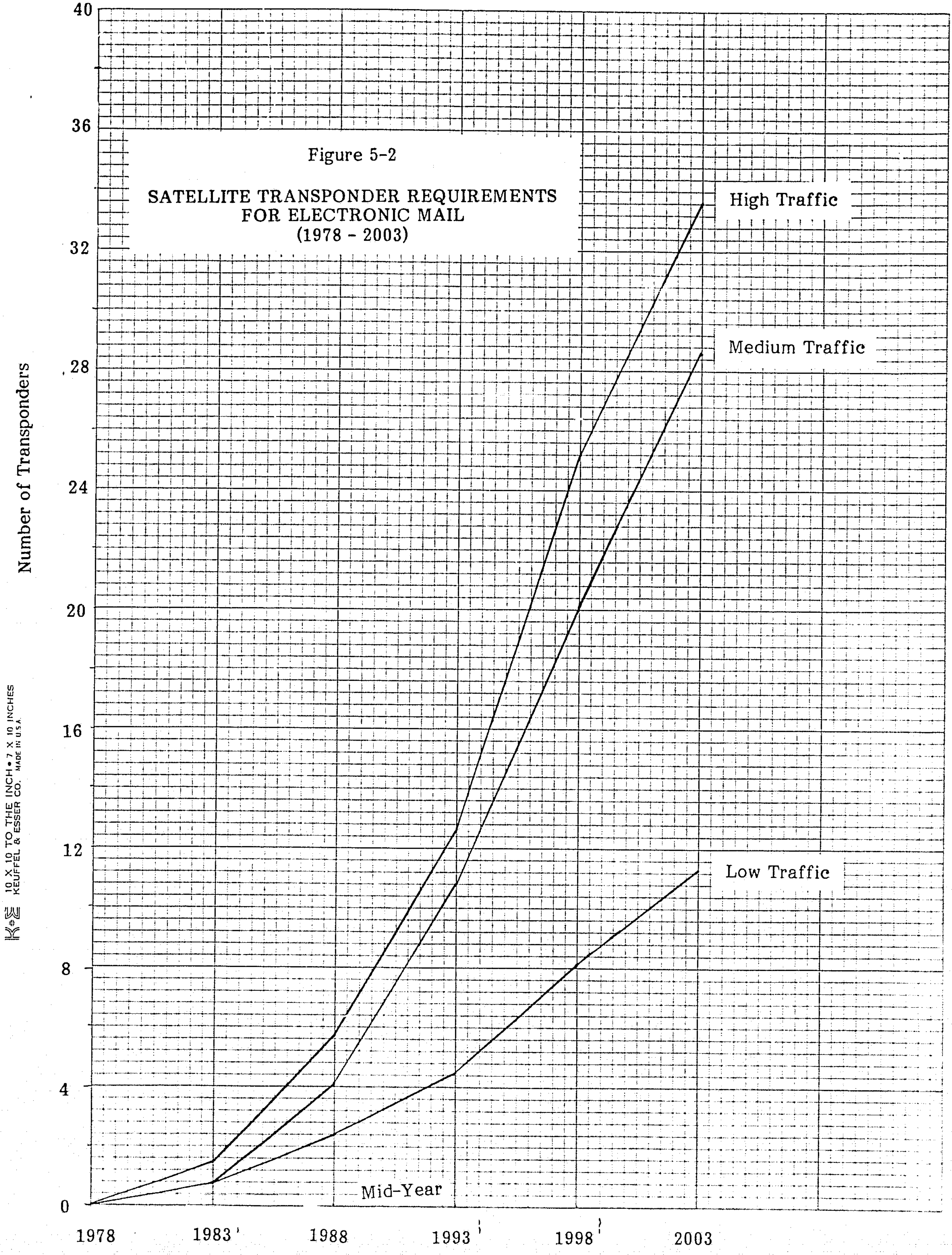

Table 5-3

1978-2003 Satellite Circuit Requirements

For Video Conferencing

(Thousands)

Traffic Scenario	1978	1983	1988	1993	1998	2003
Low	.02	.2	2.7	6.4	15.1	23
Medium	.02	.2	5.4	12.8	22.7	36
High	.02	.2	10.8	19.1	30.1	44.9

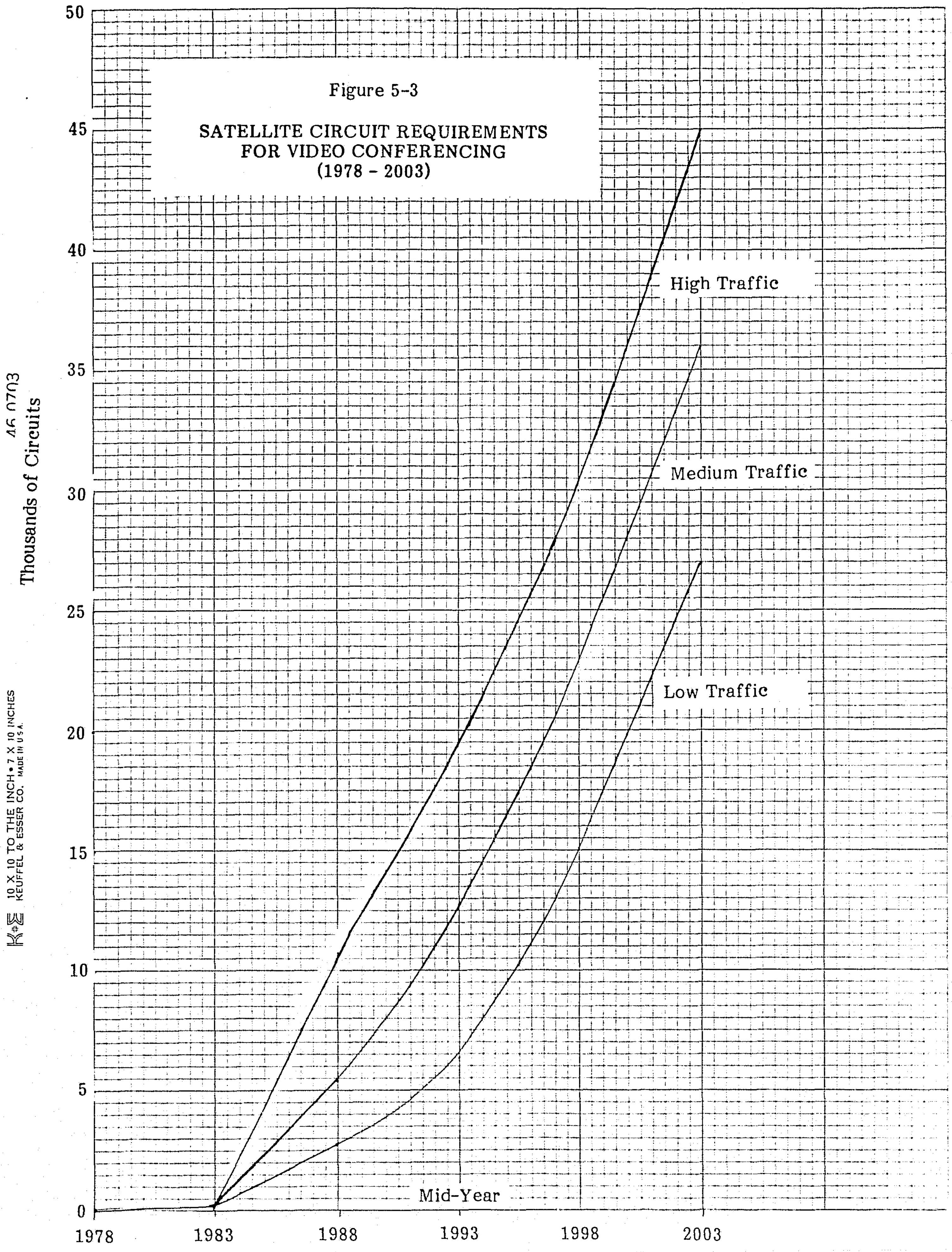

Figure 5-3
SATELLITE CIRCUIT REQUIREMENTS
FOR VIDEO CONFERENCING
(1978 - 2003)
Thousands of Circuits
50
45
40
35
30
25
20
15
10
5
0
High Traffic
Medium Traffic
Low Traffic
Mid-Year
1978
1983
1988
1993
1998
2003
10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 0703

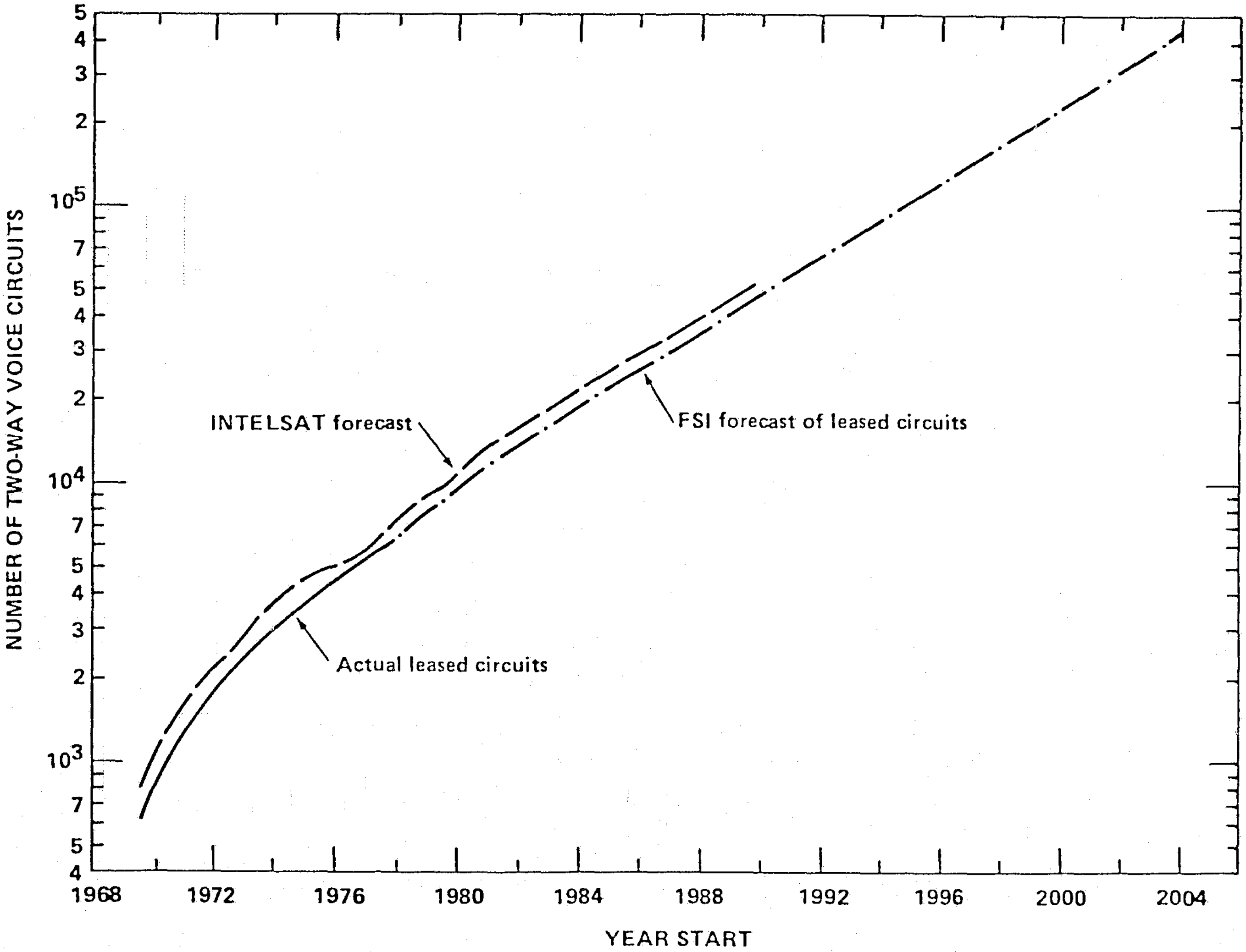

FIGURE 5-4

ATLANTIC OCEAN REGION
TRAFFIC FORECAST

Table 5-4

INTELSAT's Atlantic Ocean Region

Leased Circuit Forecast

Mid Year	Two-Way Voice Circuits
1969	800
1970	1300
71	1820
72	2450
73	3300
74	4150
1975	4800
76	5300
77	6400
78	8200
79	9800
1980	12300
81	14500
82	17000
83	20000
84	23000
1985	27500
86	31000
87	36500
88	42500
89	49500

Table 5-5

Forecast for INTELSAT's Atlantic Ocean Region

Derived from the Traffic Data Base

Mid Year	Two-Way Voice Circuits
1978	7125
1983	17400
1988	36500
1993	83500
1998	188500
2003	400000

The data presented on INTELSAT up to this point has been for international traffic. In addition to this traffic INTELSAT is presently providing service to countries for domestic communications through leased transponders. The level of this service is presently about sixteen transponders, and with more countries and groups of countries becoming interested in leasing service this type of business could become an important part of the INTELSAT System. We have developed traffic forecasts for domestic and regional satellite communications requirements for several potential users of the INTELSAT space segment. The results of this forecast are shown in Table 5-6.

Table 5-6

TOTAL REQUIREMENTS (TRANSPONDERS)
DOMESTIC AND REGIONAL SYSTEMS

MID-YEAR:	1979	1981	1983	1985	1987	1989
MEXICO	0.0	3.6	8.7	15.1	22.4	30.5
CENTRAL AMERICA	0.5	1.3	2.3	3.5	4.8	6.3
BRAZIL	3.6	9.0	16.6	26.5	37.6	49.9
ARGENTINA	0.2	1.1	2.3	3.8	5.6	7.6
ANDEAN SYSTEM	2.7	6.6	11.7	18.0	25.0	32.6
NORTHWEST AFRICA	3.6	4.9	6.8	9.3	12.3	15.8
CENTRAL AFRICA	3.3	4.7	6.5	8.7	11.4	14.6
SOUTHERN AFRICA	1.2	1.7	2.5	3.5	4.8	6.3
S. AFRICA & RHOD	0.0	0.0	1.2	3.9	6.8	9.9
SOUTHEAST ASIA	0.0	0.7	2.4	4.8	7.6	11.0
IRAN	0.0	2.1	5.6	10.4	15.6	21.3
ARABSAT	8.4	16.9	29.7	46.5	64.9	85.0
AUSTRALIA & N.Z.	0.0	1.9	6.8	13.1	19.8	26.9
TOTAL	23.4	54.6	103.2	167.1	238.5	317.7